Asphalt Mixture Pure Shear Test under the Combined Effects of Freeze-thaw and Water

Wang Daozheng, Chen Xiaoqing, LI Xiaojun

***Abstract*— Cracking of asphalt pavement seriously affects its use function, and the temperature big change is a important factor of the asphalt pavement cracking. Although both domestic and international have carried out a lot of researches on asphalt pavement freeze-thaw damage, in the evaluation of performance index of asphalt mixture performance indicators, lots of researches didn't consider the influence under the combined effects of freeze-thaw and water. What's more, there is no experimental means and standards of evaluating asphalt mixture shear failure mode under the combined effects of freeze-thaw and water, so an experimental method is designed, starting pure shear tests for the asphalt mixture with different asphalt-aggregate ratio and particle size. Prepare asphalt Mixture of different asphalt-aggregate ratio and particle size. First, put specimens in a water bath at room temperature, and make specimens in the water to keep 48 h; then remove the specimen in a plastic bag, add about 10ml of water, and tie the bag, then place it in the constant temperature(-18 ± 2℃) refrigerator about 16 hours., and finally place it in the constant temperature(60 ± 0.5℃) bath about 24 hours. By single factor theory, starting pure shear tests for the asphalt mixture with different asphalt-aggregate ratio and particle size under the condition of the freeze-thaw and water combined. Through data analysis, obtained the evolution rule of the asphalt mixture's shear strength and shear strain on different asphalt-aggregate ratio and particle size. Research indicates: Other conditions remain unchanged, the shear stress with asphalt mixture particle size increases, with the asphalt-aggregate ratio is increased and then decreased presentation. The results provide technical support and theoretical basis for asphalt road construction.**

***Index Terms*— Asphalt mixture, Shear strengths, Asphalt-aggregate ratio, Graduation**

I. INTRODUCTION

Thirty years of reform and opening up, is the fastest developing speed and the largest period in the history of our country highway traffic. Since 1988 Shenyang-Dalian and Shanghai-Jialing expressway opened by the end of 2014, China's highway traffic total mileage of 104000 kilometers. In the highway construction, because the asphalt pavement has good driving comfort, good use performance and can get the favor of people, therefore, the highway asphalt pavement mostly adopted [1]. However, with the vehicle of a big shock, overloading vehicles increase, and the formation of the channelized traffic, asphalt pavement diseases are becoming increasingly serious [2], the damage frequency is higher and higher. Many highway appeared a large area of cracks from the opening 1-2 years or more short time, caused great loss to our national economy. Enhancing the operational performance and reducing the damage of the asphalt pavement become a highly concerned problem of road workers, and also become a main problem eager to be solved of our country. From the beginning of the 1930s, domestic and international carried a lot of research on the shear strength of asphalt mixture. Bi Yufeng [3] Tongji University analyzed the causes of damage and concluded that the road is very easy to damage because of the lack of shear performance of asphalt mixture. In addition, Pan Baofeng[4], Dalian University of Technology, Wang Zheren [5], Harbin Institute of Technology, followed the accumulation of moisture migration and freezing caused by low temperature.

A lot of research on the shear strength of asphalt mixture has carried out in the United States. Which is more representative of the Norman W. Mcleod [6]、V. A. Endersby [7]、L. W. Ni jboer [8] Although both domestic and international have carried out a lot of researches on asphalt pavement freeze-thaw damage, in the evaluation of performance index of asphalt mixture performance indicators, lots of researches didn't consider the influence under the combined effects of freeze-thaw and water. What's more, there is no experimental means and standards of evaluating asphalt mixture shear failure mode under the combined effects of freeze-thaw and water, so an experimental method is designed, starting pure shear tests for the asphalt mixture with different asphalt-aggregate ratio and particle size. We can obtain the corresponding stress-strain curve, and analyze data, then conclude the best shear performance of materials. Thereby laying the foundation for road construction and engineering selection in the future.

II. TEST DESIGN

A. Test equipment:

1) 1.1.1 Test apparatus

NC pure shear tester includes a host, measuring devices, printing devices and related accessories [9] .Meanwhile, the tester host, only to make a few changes and with related accessories, you can perform a variety of tests need to be applied vertical load. Experimental apparatus is shown in fig.1.

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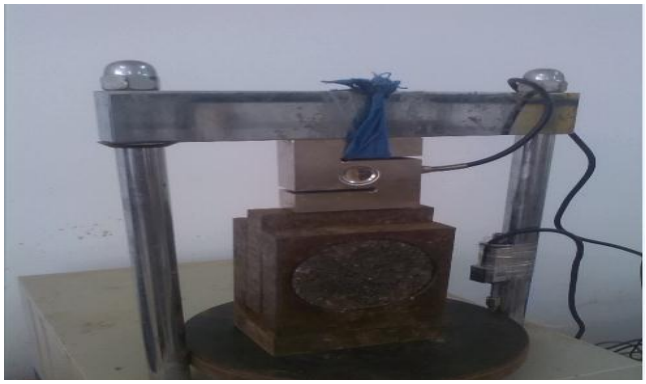

Fig.1 Marshall Stability test instrument

2) Experimental equipment loading rate

Due to 50 mm/min rate applied widely, many test equipment such as Marshall Stability is loaded at this rate. And with loading rate of 50 mm/min, the shear strength is bigger than by 5 mm/min, 10 mm/min and 20 mm/min loading rate, big test result can be a better judgment of performance. As far as possible in order to simulate the static load effect, through comprehensive consideration, finally decide to direct shear test loading rate by 50 mm/min loading rate. Therefore, in order better to determine the shear properties of asphalt mixture under the condition of the freeze-thaw and water combined, this paper experiments also use loading rate of 50mm / min.

B. Specimen preparation

Specimen preparation process according to the "highway engineering asphalt and asphalt mixture test regulation" and adopt GTM research rotation compaction molding [10-11].Specimen dimensions meet diameter 101.6mm, a height of 110mm, as shown in fig.2. GTM use rotary shear compactor experiment design method. Its mechanism is similar to the way through the rub roller compacted asphalt mixture, accurately simulates the construction site of compaction, and maximize simulates mutual friction of the tire and the road when the car driving on the road. The experiment design the tire pressure for the vertical load, according to a given angle of rotation constantly kneading and shearing, compacting specimen rub, cut, compacted specimen, until the specimen reaches balance state.

Fig.2 Test specimen

III. FREEZE-THAW OF PURE SHEAR TEST DESIGN

Diameter and height of the amount of the test pieces: On both sides of specimen by drawing symmetrical cross mark in the center of the circle, with a caliper measurement of the diameter of the central test specimen, then measured with a caliper at the symmetrical four directions from the specimen edge 10 mm in diameter, accurate to 0.1 mm, accurate to 0.1 mm, and its average value as the diameter of the specimen [12] .As the specimen does not meet 101.6mm ± 0.2mm diameter requirement or both width difference is greater than 2mm, the specimen shall be forfeited.

Steps：

1) Take 8 specimens with the same category, marked, and note the asphalt-aggregate ratio.

2) Put specimens in a water bath at room temperature, and make specimens in the water to keep 48 h.

3) Remove the specimen in a plastic bag, add about 10ml of water, and tie the bag, then place it in the constant temperature(-18± 2℃) refrigerator about 16 hours.

4) Remove the specimen and place it in the constant temperature(60± 0.5℃) bath about 24 hours.

5) Remove the specimen and set out pure shear test immediately, collect data, and make a record.

6) Repeat the above steps.

7) Data processing and analysis.

IV. FREEZE-THAW PURE SHEAR TEST DATA AND DATA ANALYSIS

A. 3.1 Test data calculating shear stress and shear strain.

By pure shear test, obtained the shear and deformation data with different asphalt-aggregate ratio and particle size, as shown in tables 1 and 2.

Table 1 Gradation AC - 13 specimens of the experimental data

Label	Asphalt-aggregate ratio (%)	Shear (KN)	Deformation (mm)
1	3.9	14.43	6.28
2	4	12.75	5.59
3	4.2	15.16	7.37
4	4.3	10.51	5.66
5	4.4	10.09	8.14
6	4.6	10.49	5.58

Table 2 Gradation AC - 20 specimens of the experimental data

Label	Asphalt-aggregate ratio (%)	Shear (KN)	Deformation (mm)
1	3.7	13.41	9.03
2	3.8	17.12	9.63
3	3.9	16.55	11.07
4	4	14.58	10.05
5	4.1	10.48	7.39
6	4.4	11.58	8.19

According to the formula (3-1), (3-2) processing the data obtained shear stress and strain

$$\delta = \frac{P}{2A} \times 10^3 \qquad (1)$$

Where: δ is shear stress(MPa)；P is pressure(KN)；A is the cross-sectional area of the specimen (m^2)

$$\varepsilon = \frac{\Delta L}{L_0} \times 100 \qquad (2)$$

Where: ε is strain(%)； ΔL is the displacement of the specimen changes(mm); L_0 is the specimen original height (mm).

According to the formulas (1) , (2),after the data analysis obtained specimen shear strength with different asphalt-aggregate ratio and particle size, as shown in Table 3 and 4.

Table 3 Gradation AC-13 specimen shear strength data

Label	Asphalt-aggregate ratio (%)	Shear strengt (MPa)
1	3.9	0.59
2	4	0.77
3	4.2	0.91
4	4.3	0.64
5	4.4	0.62
6	4.6	0.63

Table 4 Gradation AC-20 specimen shear strength data

Label	Asphalt-aggregate ratio (%)	Shear strength (MPa)
1	3.7	0.84
2	3.8	1.04
3	3.9	1.01
4	4	0.89
5	4.1	0.65
6	4.4	0.69

According to the formulas (1),(2) , after the data analysis obtained specimen shear strain with different asphalt-aggregate ratio and particle size, as shown in tables 5 and 6.

Table 5 Gradation AC-13 specimen shear strain data

Label	Asphalt-aggregate ratio (%)	Shear strain (%)
1	3.9	3.6
2	4	2.8
3	4.2	3.1
4	4.3	2.7
5	4.4	4.2
6	4.6	3.1

Table 6 Gradation AC-20 specimen shear strain data

Label	Asphalt-aggregate ratio (%)	Shear strain (%)
1	3.7	3.7
2	3.8	3.6
3	3.9	4.6
4	4	4.6
5	4.1	3.9
6	4.4	4.4

B. 3.2 Asphalt-aggregate ratio of asphalt mixture influence regularity of shear strength and shear strain.

1) 3.2.1 Asphalt-aggregate ratio of asphalt mixture influence of shear strength

Through the table 3 can obtain gradation AC-13 specimen asphalt-aggregate ratio—shear strength curve, as shown in fig.3.

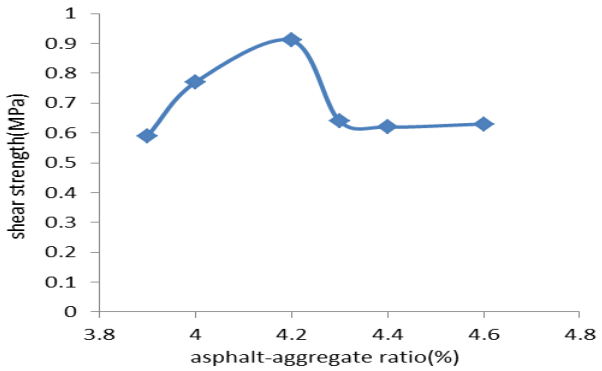

Fig.3 Gradation AC-13 specimen asphalt-aggregate ratio—shear strength curve

As it can be seen from fig.3, asphalt-aggregate ratio has a certain extent on gradation AC-13 asphalt mixture shear strength. With the increase of asphalt-aggregate ratio, asphalt mixture shear strength first increases then decreases under the condition of the freeze-thaw and water combined, which in the asphalt-aggregate ratio of about 4.2%, greater shear strength of 0.91MPa.

Through the table 4 can obtain gradation AC-20 specimen asphalt-aggregate ratio—shear strength curve, as shown in fig.4.

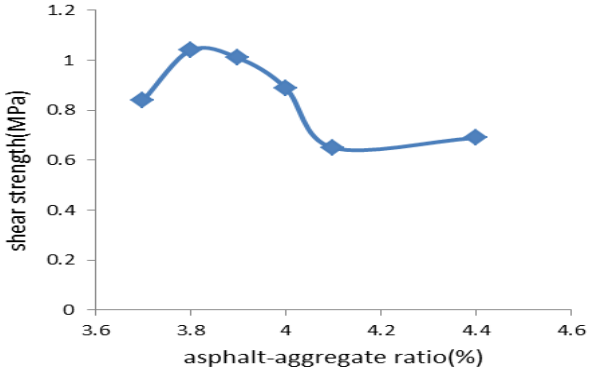

Fig.4 Gradation AC-20 specimen asphalt-aggregate ratio—shear strength curve

As it can be seen from fig.4, asphalt-aggregate ratio has a certain extent on gradation AC-20 asphalt mixture shear strength. With the increase of asphalt-aggregate ratio, asphalt mixture shear strength first increases then decreases under the condition of the freeze-thaw and water combined, which in the asphalt-aggregate ratio of about 3.8%, greater shear strength of 1.04MPa.

2) 3.2.2 Asphalt-aggregate ratio of asphalt mixture influence of shear strain

Through the table 5 can obtain gradation AC-13 specimen asphalt-aggregate ratio—shear strain curve, as shown in fig.5.

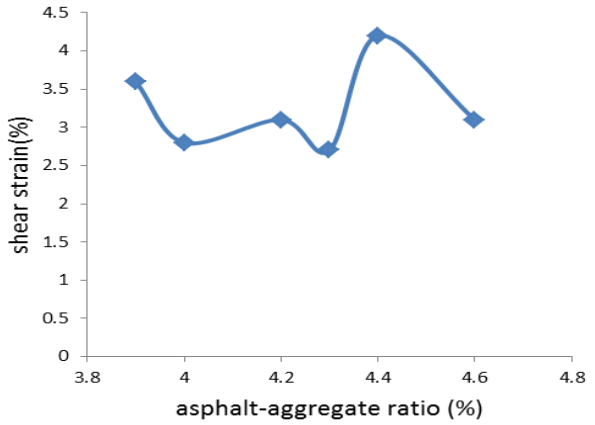

Fig.5 Gradation AC-13 specimen asphalt-aggregate ratio - shear strain curve

As it can be seen from fig.5, asphalt-aggregate ratio has a certain extent on gradation AC-13 asphalt mixture shear strain. With the increase of asphalt-aggregate ratio, asphalt mixture shear strain first decreases then increases and then decreases under the condition of the freeze-thaw and water combined, which in the asphalt-aggregate ratio of about 4.4%, greater shear strain of 4.2%

Through the table 6 can obtain gradation AC-20 specimen asphalt-aggregate ratio—shear strain curve, as shown in fig.6.

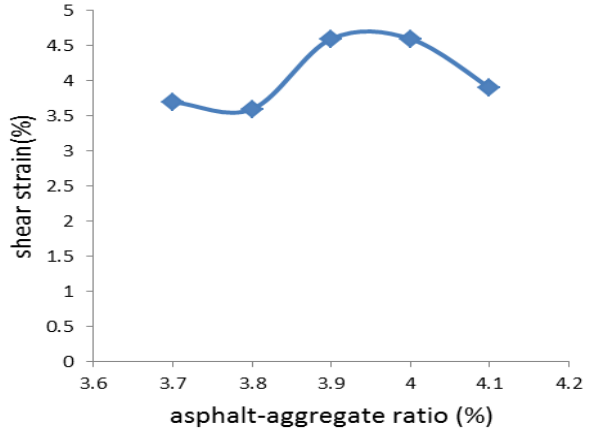

Fig.6 Gradation AC-20 specimen asphalt-aggregate ratio-shear strain curve

As it can be seen from fig.6, asphalt-aggregate ratio has a certain extent on gradation AC-20 asphalt mixture shear strain. With the increase of asphalt-aggregate ratio, asphalt mixture shear strain first decreases then increases and then decreases under the condition of the freeze-thaw and water combined, which in the asphalt-aggregate ratio of about 3.9%, greater shear strain of 4.6%

C. 3.3 Gradation of asphalt mixture influence regularity of shear strength and shear strain.

Based on the test data can be drawn AC-13 and AC-20 each shear stress and shear strain under asphalt-aggregate ratio at 3.9%、4.0% and 4.4%, as shown in table 7.

Table 7 Gradation AC-20 and AC-13 specimen under the same asphalt-aggregate ratio of shear strength and shear strain data

asphalt-aggregate ratio (%)	AC-13 shear strength (MPa)	AC-13 shear strain (%)	AC-20 shear strength (MPa)	AC-20 shear strain (%)
3.9	0.88	3.6	1	4.6
4	0.77	2.8	0.9	4.6
4.4	0.62	4.2	0.69	4.4

Through the table 7 can obtain AC-20 and AC-13 specimen shear strength and shear strain histogram under the same asphalt-aggregate ratio, as shown in fig.7 and fig.8.

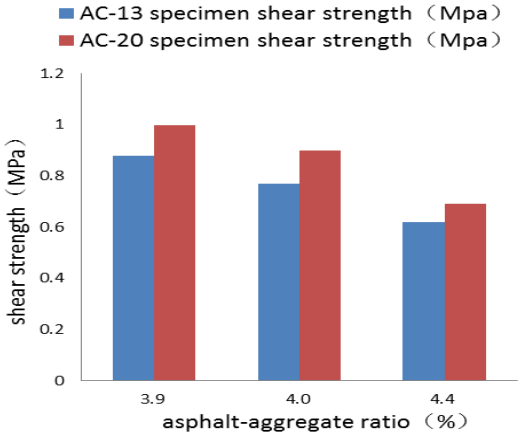

Fig.7 AC-20 and AC-13 specimen shear strength histogram under the same asphalt-aggregate ratio

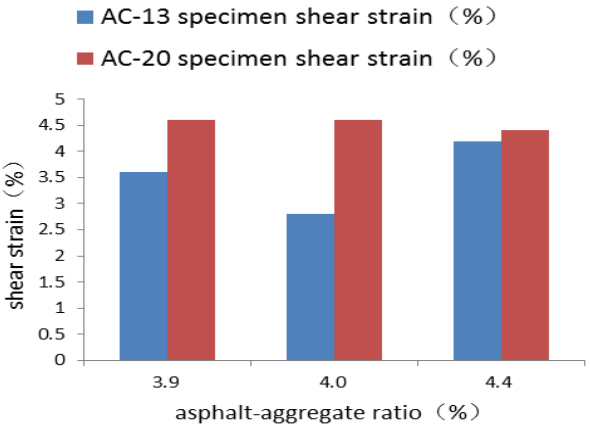

Fig.8 Gradation AC-20 and AC-13 specimen shear strain histogram under the same asphalt-aggregate ratio

From fig. 7 and fig.8 can be concluded that gradation has a certain extent on asphalt mixture shear strength, in the same asphalt-aggregate ratio AC-13 specimen shear strength and

shear strain is smaller than AC-20 specimen under the condition of freeze-thaw and water combined, that is: in the same asphalt-aggregate ratio, with the increase of maximum particle size asphalt mixture shear strength is also increased.

V. CONCLUSION

In this paper, shear tests were carried out on AC-13 and AC-20 asphalt mixture to study gradation and asphalt-aggregate ratio on the influence of asphalt mixture shear strength under the condition of freeze-thaw and water combined. Through the above table and figure content analysis the following conclusions:

(1) Gradation has a certain extent on asphalt mixture shear strength. This paper selects AC-13 and AC-20 specimen, according to the relevant data can be seen that in the same asphalt-aggregate ratio with the increase of maximum particle size asphalt mixture shear strength and shear strain is also increased under the condition of freeze-thaw and water combined.

(2) Asphalt-aggregate ratio is also one of the factors on asphalt mixture shear strength. Under the same grading, with the increase of asphalt-aggregate ratio, asphalt mixture shear strength first increases then decreases, and appears maximum shear strength, at this time is the respective optimum asphalt-aggregate ratio.

(3) As can be seen from the above analysis, shear strength test method proposed in this paper can distinguish asphalt mixture shear performance advantages and disadvantages with different asphalt-aggregate ratio and particle size. But there are still many deficiencies, we need to be supplemented and perfected in subsequent experiments.

REFERENCES

[1] Rao Jinan. Stay on Road Performance of Mixture Asphalt LMT [M].Beijing: China Communications Press, 2001
[2] Wudao Impact of freeze-thaw cycles on the performance of asphalt mixture [D]. Wuhan University of Technology.2011
[3] Bi Yufeng Highway engineering in shortest time limit for a project under limited resources optimization analysis [J] East China Highway, 2003(02)
[4] Pan Baofeng. Test and study of the alternate freezing and thawing capability of the bituminous mixture. [J]. China Journal of Highway and Transport, 2003(02)
[5] Wang Zheren. Water damage to asphalt pavement in cold area highway [J].Technology of Highway and Transport,1999(04)
[6] PLARC Technical Commute on Flexible Roads, Bituminous Materials with a High Resistance to Flow Ruitting [J].1995
[7] V. A. Endersby, The history and theory of triaxial testing and preparation of realistic test specimens, A.S.T.M. [J].San Francisco, October, 1949
[8] L. W. Ni jboer, Plasticity as a factor inroad, Elsevier Publishing CO.INC.1948the design of dense bituminous carpets Amsterdam [J].New York, London, Brussels, 1948
[9] Gaofeng Experimental study of asphalt mixture performance at low temperature [D]. Jilin University.2007
[10] Jia Jingfeng Research on anti-cracking of high-performance asphalt mixture at low temperature [D]. Chongqing Jiaotong University.2007
[11] Bi Yufeng Highway engineering in shortest time limit for a project under limited resources optimization analysis [J] East China Highway, 2003(02)
[12] Highway engineering asphalt and asphalt mixture test regulation [M]. TG E20-2011. Research Institute of Highway Ministry of Transport. 2011